Targetry Fabrication for Nuclear Data Measurements: What Works (and what doesn't!)

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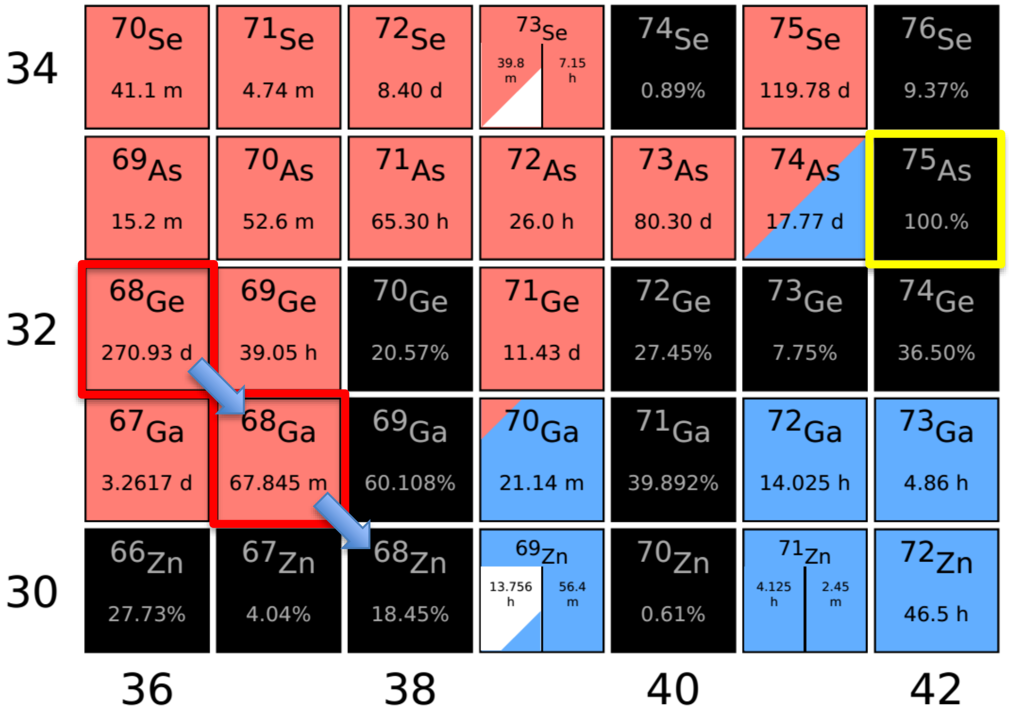
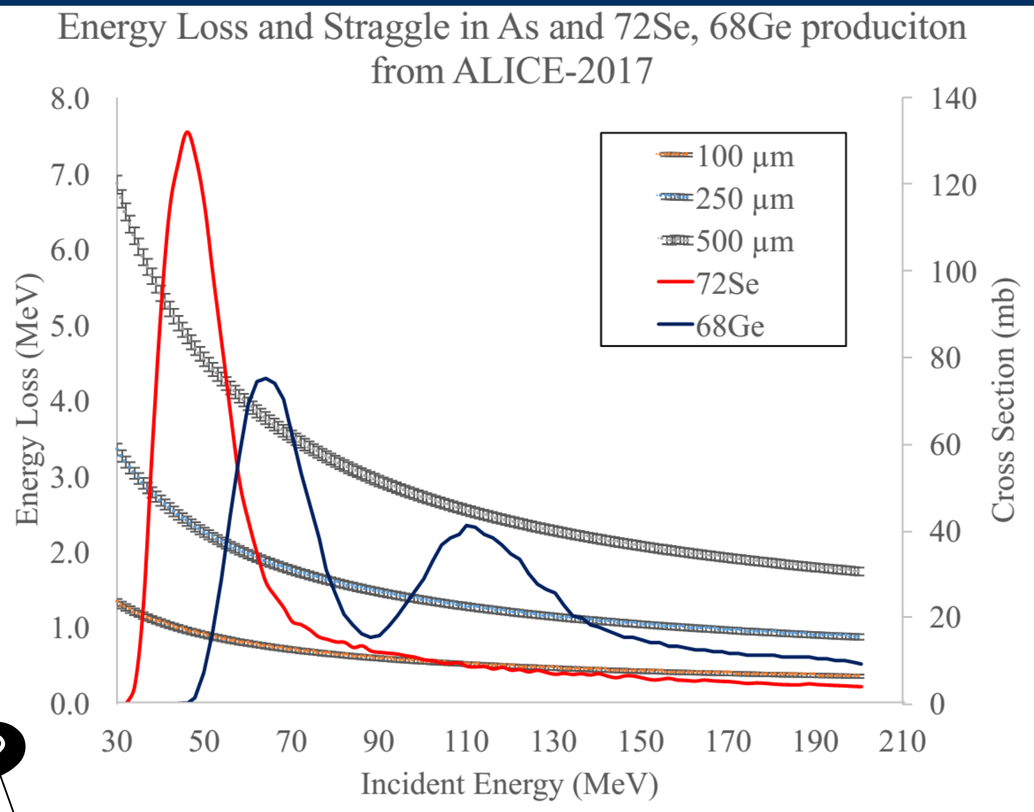
The Targetry "Balancing Act"



Goal: 25-50 μm thickness (~13-26 mg/cm²)



- Goodfellow / AlfaAesar / Sigma:
  - Only bulk "lumps" **~20mm**
- American Elements: **< 10 μm or > 2 mm**
  - Communication issues…

- Semiconductor Industry: 5—1000+ mm
  - GaAs / GeAs
- Plasma Deposition: < ~10 mm

In-House Fabrication: What Doesn't Work

Arsenic is a near-perfect example of when common fabrication techniques are inapplicable

- Three major allotropes:
  - Gray arsenic: semi-metallic, brittle
  - Yellow arsenic: waxy, rapidly oxidizes
  - Black arsenic: glassy, brittle

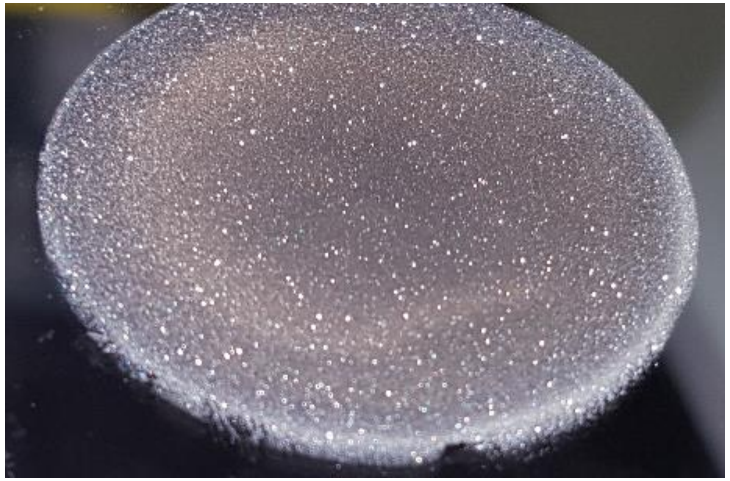
- Cold / hot rolling, extrusion causes significant cracking
- Impossible to cast – arsenic sublimes upon heating!
- Machining, laser/water cutting destroys bulk substrate
- Highly toxic, very difficult to fully remediate contamination with bulk quantities

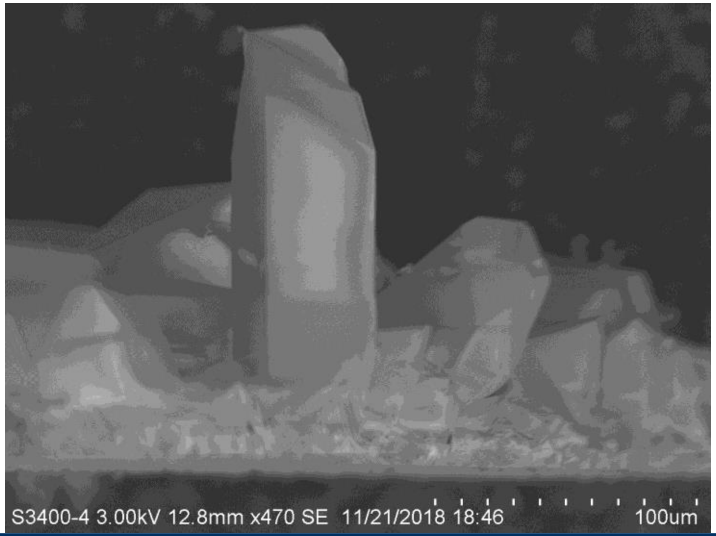
HISTORY

White arsenic has been known for centuries. In Ancient Rome, Nero's supposed use of it to poison his brother & become emperor is one of the first documented cases.

In the 17th & 18th centuries, white arsenic's use as a poison was widespread, and earned it the nickname 'inheritance powder'. However, its usage as a poison rapidly declined after the development of chemical tests.

In-House Fabrication: What (Almost) Works





Vapor deposition of As @ ORNL

- **New As stock is crucial** – As_2O_3 from old material deposits preferentially
- Produces bulk crystalline structure
- Difficult to lift target from glass slide support without causing cracks
  - Deposition straight onto Kapton avoids this!
- Quick and easy preparation method!
  - Targets > 50μm crack from stress
  - Targets < 50μm have pinholes and thin spots visible to naked eye
- Deposition onto thin copper foil appears promising, but needs more investigation
  - Can revisit if interest / need exists!

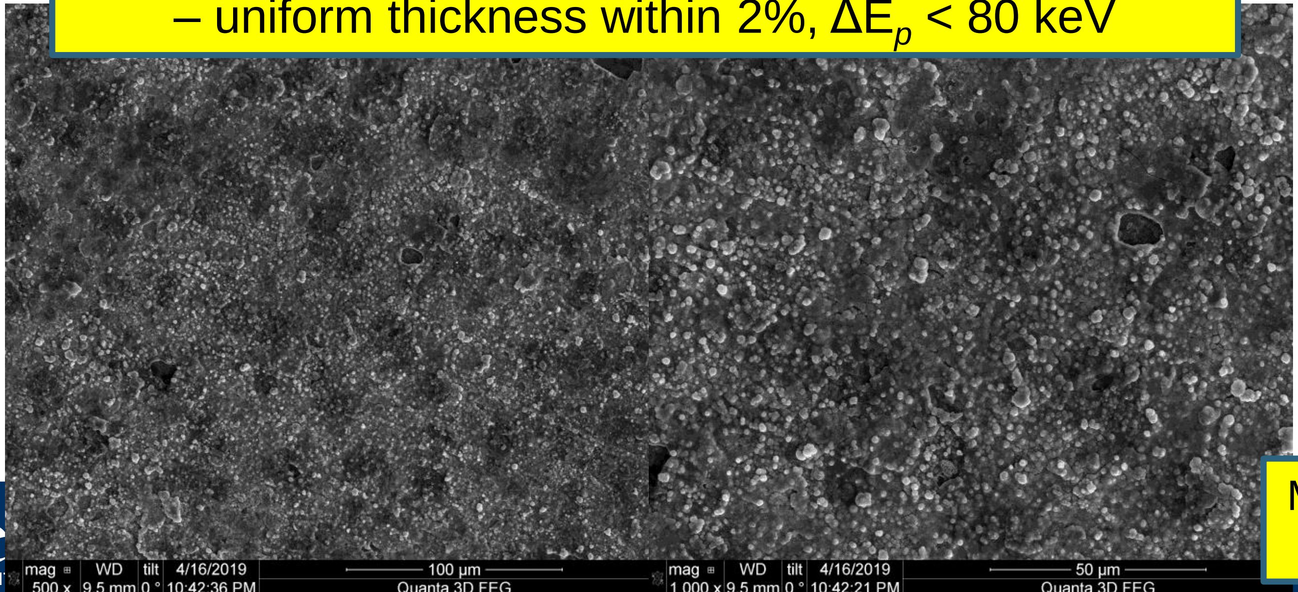
Targets are currently not sufficiently uniform for nuclear data measurements

In-House Fabrication: What Does Work

[1] JRNC 282.2 (2009): 365-368.

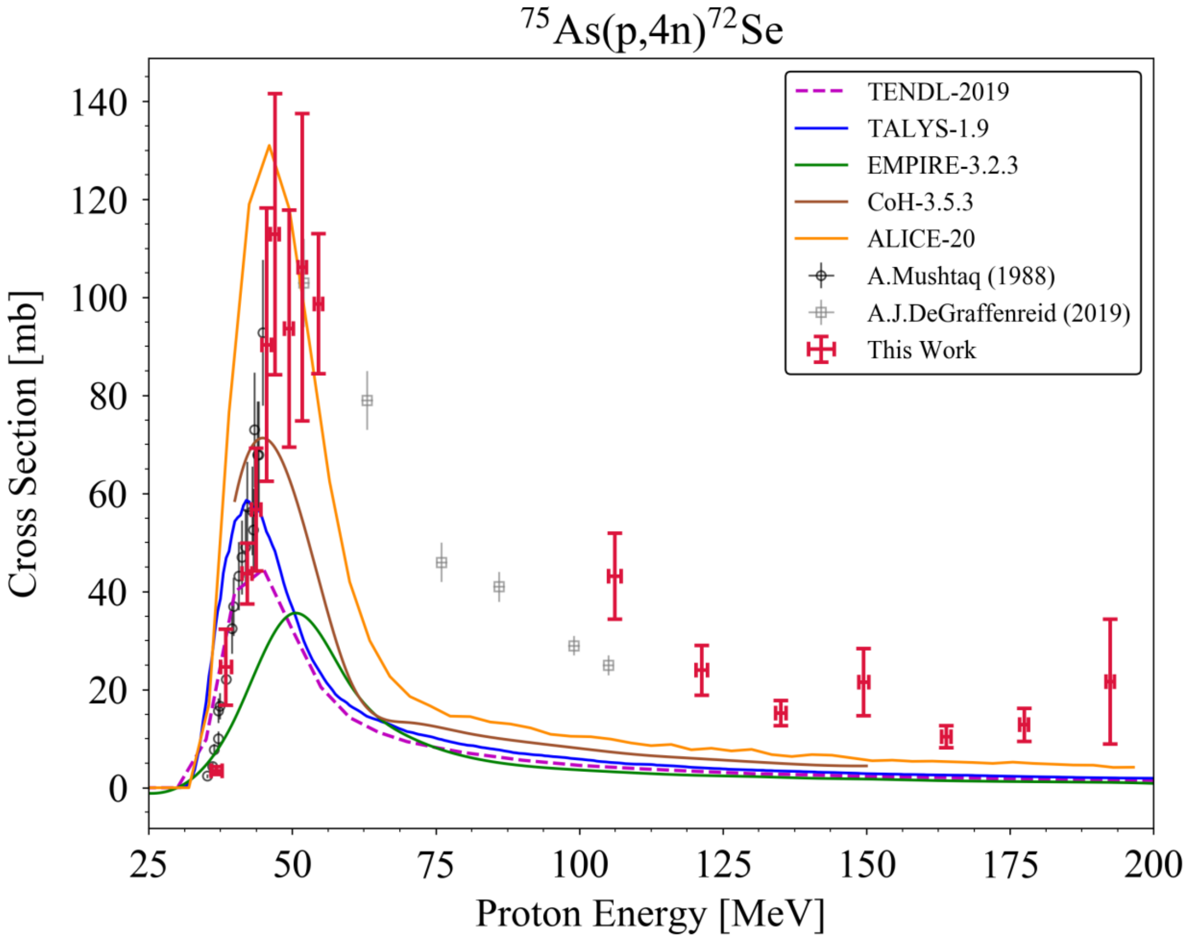
- Deposition onto 10um titanium foil[1]:
  - As_2O_3 (12.5 g/L) in 7M HCl, @ 130 mA

Developed plating capabilities with masses ranging 2-17 mg (approximately 1-10 µm, or 0.5-4.5 mg/cm^2) – uniform thickness within 2%, ΔE_p < 80 keV

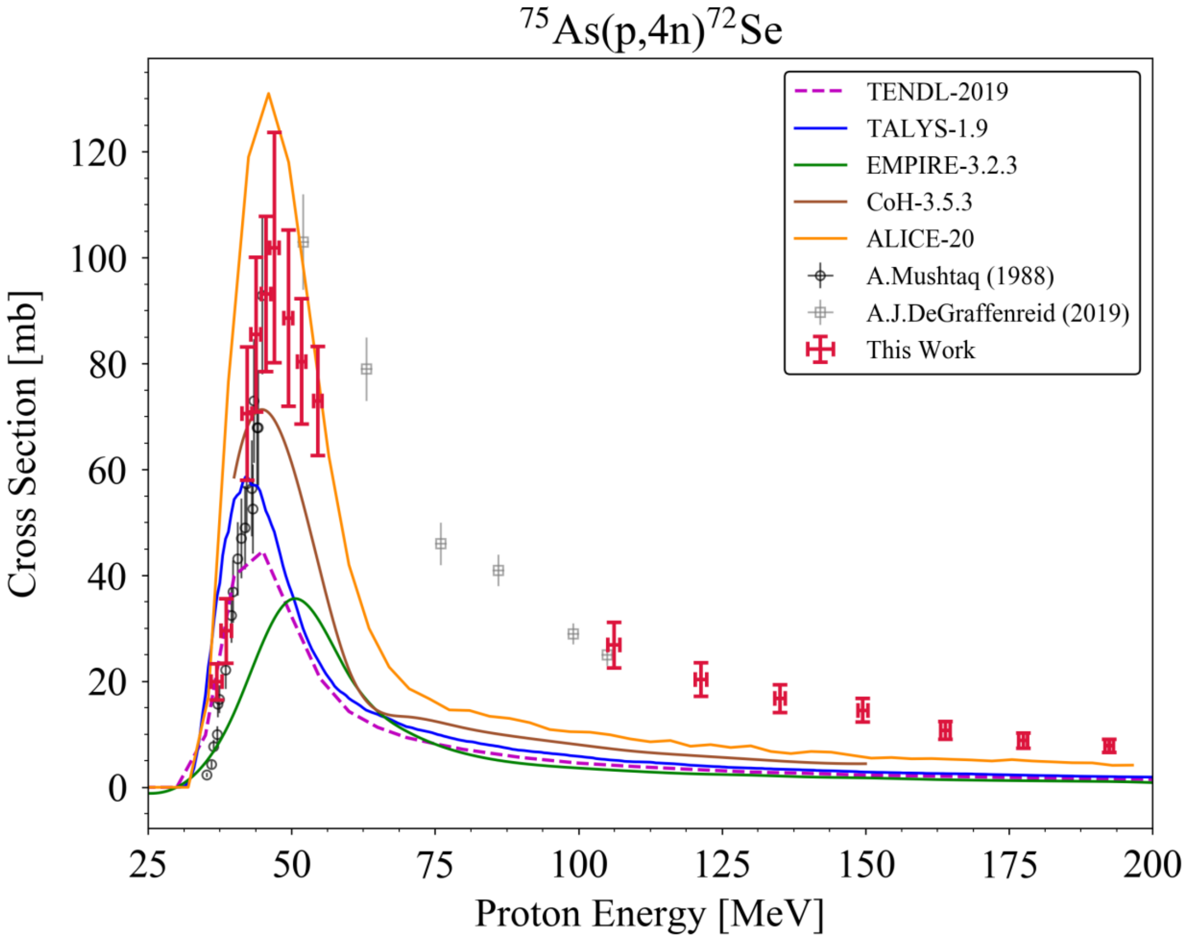


Major drawbacks: thickness characterization, difficult to plate > 10 µm without developing significant stress & flaking

In-House Fabrication: What Does Work



Thickness via mass measurement



Thickness via reactor activation

In-House Fabrication: What Could Work?

Additional deposition methods:

- As_2O_3 (0.2M) in 1:2 molar choline chloride : ethylene glycol deep eutectic solvent[1], @46 mA
- Aluminum backing foil reduces γ background!
- Produces visually attractive target, but unknown composition…

Vibrational / Electrostatic Powder Pressing[2]

- Relatively new technique, currently being used to explore Ti production target fabrication[3]
- Very efficient! Typical 95-98% sample utilization
- Scoping out prototype designs w/ UW (E. Dorman)

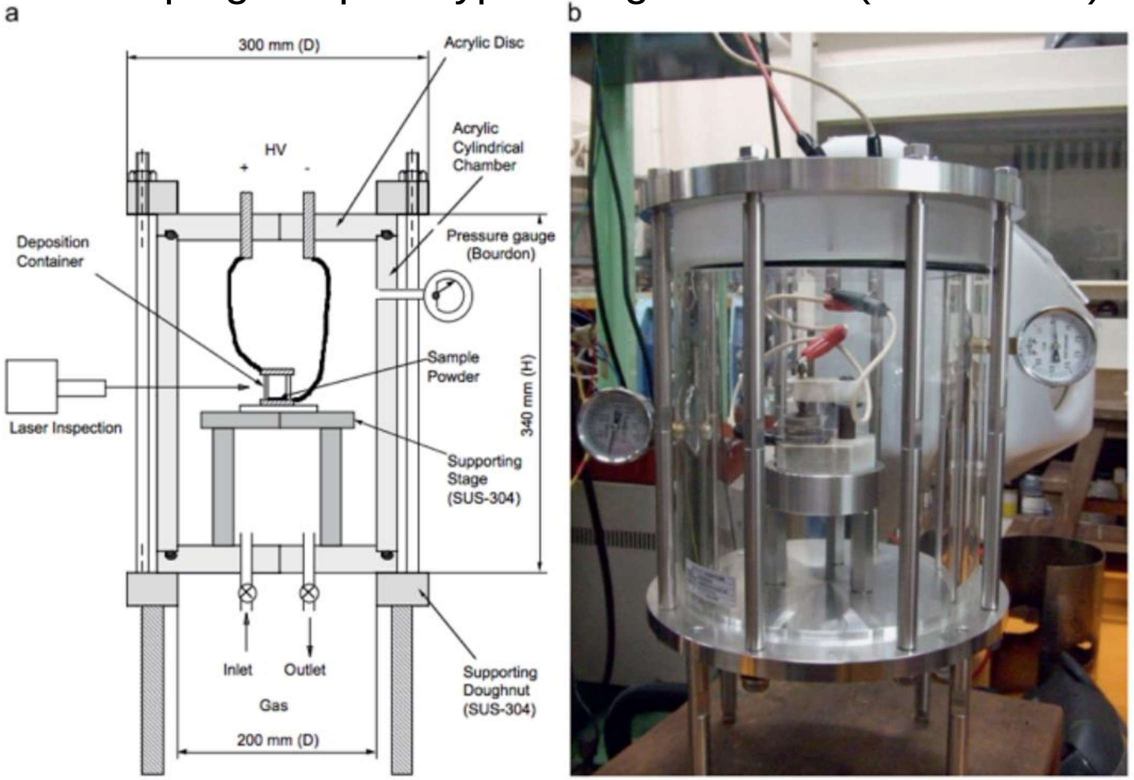
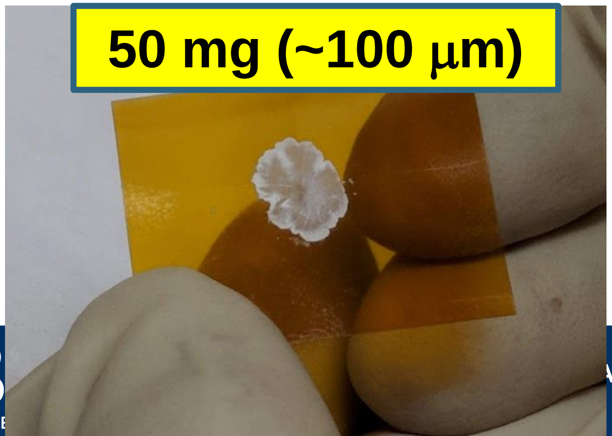
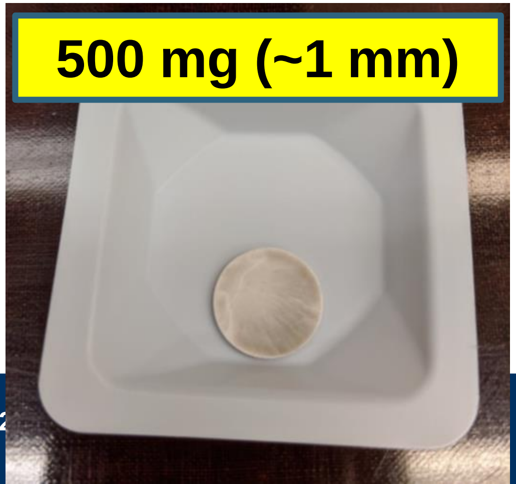


Fig. 2. (a) Cross-sectional drawing of the HIVIPP chamber for high-pressure operation and (b) a photograph.

Powder pressing via hydraulic press and trapezoidal dies:

- For Ø > 5mm, difficult for targets < 100μm
- At Ø = 10mm, easy to prepare targets > 250μm
- As_2O_3 presses nicely, As requires binder
- Non-ideal for data measurements, but potentially viable for production targets?





[1] *J Electrochemical Society* 164.4 (2017): D204-D209.
[2] NIM A 397.1 (1997): 81-90.
[3] Molecules 24.1 (2019): 20.

Collaborators on this Work

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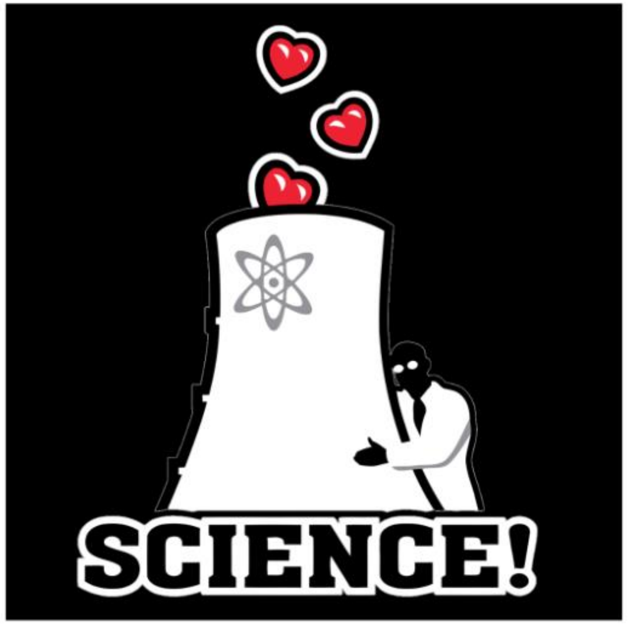

U.S. DEPARTMENT OF ENERGY

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